COST AND PERFORMANCE REPORT

Pump and Treat of Contaminated Groundwater at the Odessa Chromium I Superfund Site Odessa, Texas

September 1998

EPA

Prepared by:

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

SITE INFORMATION

Identifying Information:

Odessa Chromium I Superfund Site
Operable Unit 2 (OU 2)
Odessa, Texas

CERCLIS #: TXD980867279

ROD Date for OU2: September 8, 1986

Treatment Application:

Type of Action: Remedial

Period of operation: 11/93 - Ongoing
(Monitoring and mass removal data collected through December 1996)
(Data on volume treated collected through January 1998)

Quantity of material treated during application: 125 million through January 1998

Background [1, 2, 3]

Historical Activity that Generated Contamination at the Site: Metals plating

Corresponding SIC Code: 3471, Plating of Metals

Waste Management Practice That Contributed to Contamination: Improper disposal practices

Location: Odessa, Texas

Facility Operations:

- In 1977, the Texas Natural Resources Conservation Commission (TNRCC) investigated citizen complaints of poor drinking water quality in private wells and discovered elevated levels of chromium in the groundwater. The 0.4-acre facility at 4318 Brazos Avenue was identified by EPA as the source of chromium contamination.

- Metals plating and chrome plating facilities operated at the site from 1954 to 1977, producing chromium and other metals-containing wastewater. Operations at the site ceased in 1977.

- High levels of chromium were detected in the soil and groundwater. The chromium contamination was caused by discharge of chromium-containing wastewater into unlined dirt ponds, directly to the soils, and into a septic tank drain field. Contaminants are also suspected to have migrated into the aquifer through an abandoned open well bore on the site.

- In 1984, the building, foundation, and soils contaminated with chromium were excavated and disposed. Shallow soils, down to approximately two feet, were removed. The remaining soils at the site were found to contain other heavy metals at detectable levels, but at levels that posed no apparent risk to human health and the environment.

- From 1977 until 1985, the TNRCC conducted drinking water well surveys to determine the extent of the chromium contamination.

- The Odessa I site was added to the National Priority List (NPL) in September 1984.

- The Remedial Investigation and Feasibility Study (RI/FS) was completed in 1986.

Regulatory Context:

- For the Odessa I site, EPA issued two Records of Decision (ROD): Operable Unit 1 (OU1) to address the need for an alternative drinking water supply and Operable Unit 2 (OU2) to address groundwater cleanup.

- In 1986, through the ROD for OU1, an alternate drinking water source was made available to replace water previously supplied by the contaminated wells.

- On March 18, 1988, the ROD for OU2 was approved for groundwater remediation. Further soil removal was not required by the ROD.

SITE INFORMATION (CONT.)

Background (Cont.)

- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), § 121, and the National Contingency Plan (NCP), 40 CFR 300.

Groundwater Remedy Selection: Extraction of the groundwater and treatment of chromium through ferrous ion reduction, followed by reinjection of treated water to the aquifer, was determined to be the most appropriate remedy for groundwater based on treatability studies.

Site Logistics/Contacts

Site Lead: State

Oversight: EPA

Remedial Project Manager:
Ernest Franke
U.S. EPA Region 6
First Interstate Bank Tower
at Fountain Place
1445 Ross Avenue
12th Floor, Suite 1200
Dallas, TX 75202-2733
(214) 655-8521

*Indicates primary contact

State Contact:
Lel Medford*
Texas Natural Resources Conservation Commission
P.O. Box 13087
Austin, Texas 78711
(512) 239-2440

Treatment System Vendor:
Design and Management: IT Corporation (ITC)
Construction and Operation: WATEC

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1,2,4,9]

Primary Contaminant Group: Chromium

- The contaminant of concern is chromium. The groundwater is contaminated with the hexavalent chromium species. However, cleanup standards are set for total chromium. Likewise, laboratory analyses test for total chromium. For these reasons, chromium levels tested and regulated at the Odessa I site are for total chromium. No organic contaminants were detected in the soil or groundwater.
- During a 1985 sampling event, chromium was detected in the groundwater at levels up to 72 mg/L. During sampling events in 1993, prior to pump and treat application, chromium was detected at levels up to 4.3 mg/L.
- The chromium plume directly beneath the former on-site building was heavily concentrated in the Trinity Sands, which is the major aquifer in the region. The remnants of the Ogallala Aquifer found at

MATRIX DESCRIPTION (CONT.)

Contaminant Characterization (Cont.)

the site contain a few feet of saturated thickness at the most. The northern plume migration concurs with the north-northeasterly groundwater flow direction observed during the RI/FS.

- The initial volume of the chromium plume was estimated in the 1986 RI/FS to be 15 million gallons between 44th and 48th streets. The areal extent of the initial plume was estimated to be approximately 283,000 square feet, based on a chromium contour of 0.05 mg/L.
- The ROD required the chromium levels in the groundwater to meet the maximum contaminant level (MCL) for chromium. EPA changed the MCL from 0.05 to 0.10 mg/L in 1990.
- Figure 1 illustrates the boundaries for the chromium plume for 1994, 1995 and 1996. From 1994 and 1996, the surface area of the chromium plume has decreased from 440,000 ft^2 to 247,000 ft^2, a reduction in plume size of 44%. The areal plumes are based on a total chromium concentration contour of 0.1 mg/L.

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology: [4,9]

Two distinct hydrogeologic units have been identified beneath this site. Soil and sandy caliche overlie the water-bearing formations. The first water-bearing unit is encountered at approximately 30 to 45 feet below ground surface.

Unit 1	Ogallala Formation (Perched Zone)	This unit is formed of fluvial plastics consisting of fan deposits of fine to coarse grained sands, silt, clay, and occasional strings of gravel. There are only erosional remnants of this formation present in the site area, with a saturated thickness of less than 10 feet in the lower most portion. The erosional remnants of the Ogallala are hydraulically connected to the underlying Trinity Sand Aquifer, and water from the Ogallala flows into the Trinity. The Ogallalla does not exist as a continuous aquifer and thus flow direction could not be measured.
Unit 2	Trinity Sand Aquifer	This unit consists of sands and ferragiorous calcite cemented sandstones. Settled lenses of gravel, clay, and siltstone occur at irregular intervals. This unit is the primary groundwater water supply for municipal and private residences in the area. It is underlain by the Chinle Formation, which acts as an effective aquitard. Groundwater in this unit in the area of the site was observed to flow north to northeast, which concurs with the spread of the plume from the source. However, changes in water levels have altered groundwater flow direction.

The water level in the Trinity Sand Aquifer has risen over 25 feet from 1986 to 1993. The rise in the water table is attributed to the decrease of public and private wells using the aquifer and to increased precipitation during this period.

MATRIX DESCRIPTION (CONT.)

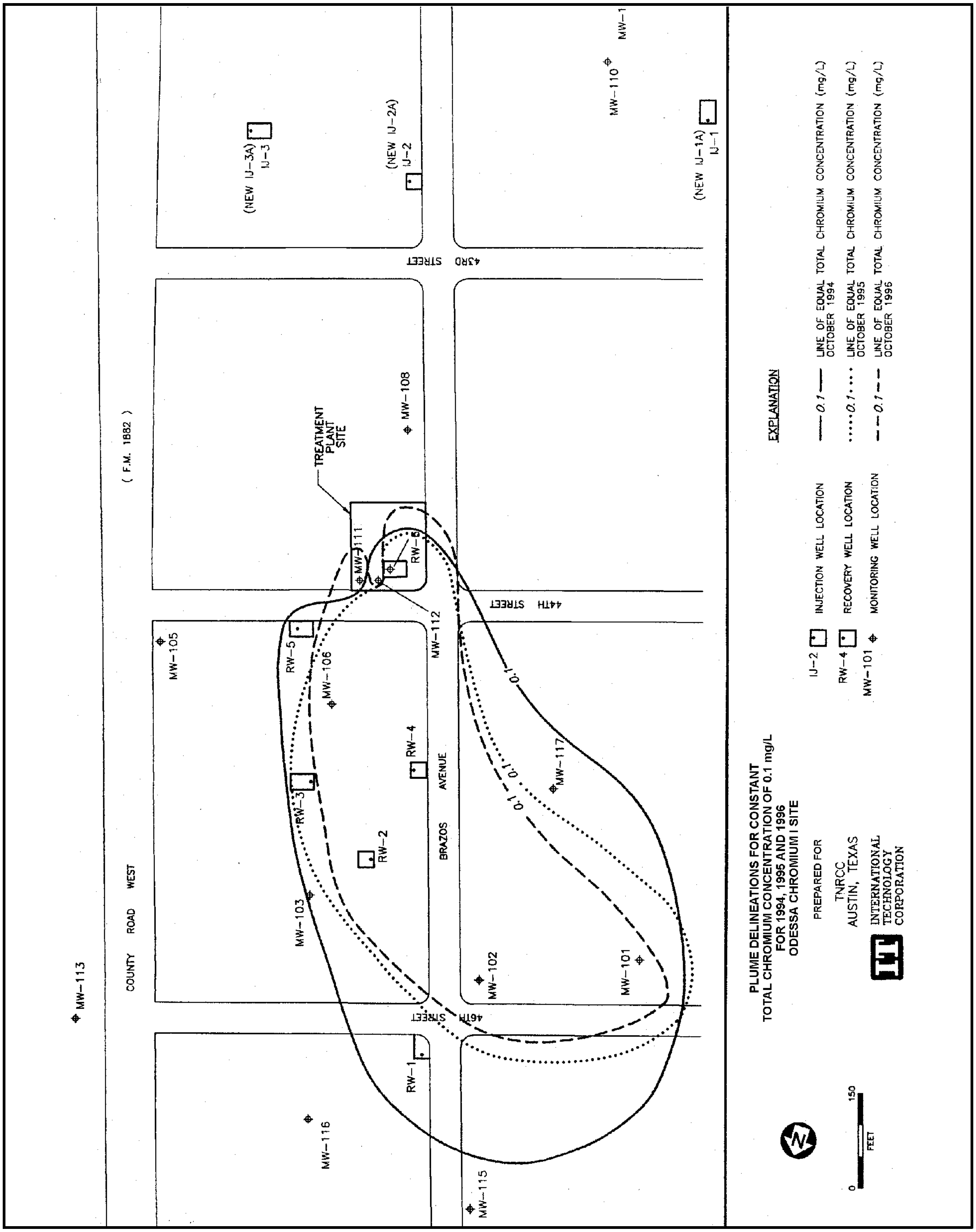


Figure 1. Chromium Concentration Contour Map, 1994 - 1996 [9]

MATRIX DESCRIPTION (CONT.)

Tables 1 and 2 include technical aquifer information and technical well data, respectively. Extraction wells are discussed in the following section.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Flow Velocity (ft/day)	Flow Direction
Unit 1 (Ogallala)	0 - 10	1.6	0.02	Not Characterized[1]
Unit 2 (Trinity Sand)	70	1.7 - 5.1	0.03 - 0.00	North-Northeast[2]

[1]Water flows from the Ogallala to the Trinity, but the direction of flow has not been characterized.
[2]Flow observed during the 1986 remedial investigation was towards the north-northeast. However, the water table rose from 1986 to 1993 by 25 feet. Flow observed during a 1993 investigation was towards the southeast. Groundwater investigations since 1993 have shown groundwater flow direction to be northerly.

Source: [4]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with electrochemical precipitation of chromium using ferrous ion

Supplemental Treatment Technology

None

System Description and Operation

Table 2. Extraction Well Data

Well Name	Unit Name	Depth (ft)	Design Yield (gal/day)
RW-1/102	Trinity Sand	138	14,400
RW-2	Trinity Sand	138	14,400
RW-3	Trinity Sand	138	14,400
RW-4	Trinity Sand	138	14,400
RW-5/106	Trinity Sand	138	14,400
RW-6	Trinity Sand	138	14,400

Source: [4]

System Description [4, 5]

- The extraction system consists of six recovery wells, located in the Trinity Aquifer (Unit 2). No recovery wells were placed in the Ogallalla Formation, directly beneath the site because only erosional remnants of the Ogallalla remain in the vicinity of the Odessa I site. In addition, the groundwater in this zone flows directly into the Trinity Aquifer. A computer model was used to determine well placement and design extraction rates in the Trinity Aquifer. The modelling determined capture zone for the plume that exceeded 0.1 mg/L chromium.

- ITC used Randomwalk to model solute transport (an in-house model by Reed and Associates) and Geoflow to model groundwater flow (an in-house model by ITC).

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- The metals treatment system is designed to treat the collected groundwater at a rate of 60 gpm. Influent tanks regulate flow through the treatment system.

- Water from the extraction wells is sent to a dual-chamber reaction tank. Ferrous ion is fed into the first chamber and mixed with the contaminated well water. Ferrous ion is produced on site in an electrochemical cell. The ion reduces the hexavalent chromium to trivalent chromium, to facilitate subsequent hydroxide precipitation. In the second chamber of the reaction tank, pH is adjusted to the range of 8.5 to 8.8 to achieve minimum solubility for chromium hydroxide. Also in the second chamber, ferrous ion is oxidized by aeration to insoluble ferric ion and converted to ferric hydroxide. Both the ferric and the chromium hydroxide are mixed with a poly-electrolyte in the second chamber.

- The treated water is clarified through a flocculation and precipitation tank, where insoluble hydroxides are precipitated out. From here, the treated water is polished through a multimedia filter for reinjection. A backwash unit stores a portion of the treated water, which is used to flush the filter at least once every 24 hours. The sludge from the clarifier is disposed off site.

- Chromium concentrations in the influent and the effluent from the treatment system are monitored continuously. If the level of chromium exceeds 0.05 mg/L in the effluent, it is pumped back through the treatment system. Treated water with chromium concentrations less than 0.05 mg/L is injected through a network of six injection wells.

- A network of 14 monitoring wells placed in the Trinity Aquifer is used to monitor plume containment quarterly. The six recovery wells are monitored on a monthly basis for water quality parameters as well.

System Operation [4,5,6,7]

- Quantity of groundwater pumped from the aquifer by year is:

Year	Volume Pumped (gal)
1992	361,000*
1993	5,339,885*
1994	28,400,155
1995	30,692,836
1996	30,598,566

*The volume pumped during 1992 was during a 30-day unsuccessful trial run. The extraction system operated only for the months of November and December in 1993.

- Initial startup began in July 1992. The injection wells and the filter began to clog with iron and calcium in the first 30 days of system operation. The extraction and treatment systems were shut down for the following alterations.

  -- The reactive tank was altered from a single-chamber to a two-chamber tank, separated by a baffle. The second chamber allowed for further precipitation of iron, the cause of clogging.

  -- A backwash unit was added after the multi-media polishing filter to unclog the filter of iron and other precipitates. The pH of the water after the clarifier was reduced to less than 7.5.

  -- Original injection wells continued to be used, but infiltration rates had slowed because of clogging. Three additional injection wells were constructed to increase the injection rate.

  -- After modifications were made from May 1993 to August 1993, the system resumed operation in November 1993.

  -- Backwash water is stored in the modified backwash unit and is added slowly to the influent tank. The slow addition avoids upsetting the pH balance in the influent tank.

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- Based on sampling events from 1993 to 1995, the higher chromium concentrations appeared to be migrating to the northwest. Recovery wells RW-1 and RW-5 were shut down and monitoring wells MW-102 and MW-106 were converted to recovery wells to continue pumping from areas in the plume with high chromium concentrations.

- One injection well was found to continually plug because of a local formation of silty fines. It was taken off line in May 1995. The rate of injection of treated water remained the same.

- The site has been operational 95% of the time since 1993. Downtime is primarily due to shutdowns for local brown outs and system maintenance.

Operating Parameters Affecting Treatment Cost or Performance

The major operating parameter affecting cost or performance for this technology is extraction rate. Table 3 presents the values measured for this and other performance parameters.

Table 3. Performance Parameters

Parameter	Value
Average Pump Rate	86,500 gpd*
Performance Standard (effluent)	0.05 mg/L total chromium
Remedial Goal (aquifer)	0.10 mg/L total chromium

Source: [2, 6]

*The average system extraction rate from January 1998 until December 1996 was estimated for this report to be 86,500 gpd or approximately 14,400 gpd per well, based on the actual 125 million gallons pumped and 95% operating rate.

Timeline

Table 4 presents a timeline for this remedial action.

Table 4. Timeline

Start Date	End Date	Activity
January 1992	July 1992	Remediation system constructed
July 1992	August 1992	System started; injection wells clogged with iron and calcium
May 1993	August 1993	Alterations made to remedial system
November 1993	---	Continuous operation of remediation system begun. Monthly monitoring of groundwater begun.
April 1995	---	Shift in plume detected. Monitoring wells MW-102 and MW-106 converted to recovery wells RW-102 and RW-106. RW-1 and RW-5 shut down
May 1995	---	Injection Well IJ-2 taken off line because of plugging

Source: [2, 4, 6, 7]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [2]

- The cleanup goals as established by TNRCC and EPA are to remediate groundwater so that chromium levels are less than the maximum contaminant level (MCL), or the Primary Drinking Water Standard, of 0.10 mg/L. This goal is applied throughout the aquifer, as measured in all on-site monitoring wells.

Additional Information on Goals

- The original drinking water standard for chromium set by EPA was 0.05 mg/L. In 1990, EPA revised the standard to the Primary Drinking Water Standard of 0.10 mg/L.

Treatment Performance Goals [4]

- Effluent injected into the aquifer from the treatment system must have levels of chromium below 0.05 mg/L.
- As a secondary goal, the remedial system is required to create an inward gradient toward the site to contain the plume.

Performance Data Assessment [1, 3, 4, 5, 6, 7]

- Three wells have met the cleanup goal for chromium of 0.10 mg/L: RW-1, RW-3, and RW-5. The maximum concentration of chromium detected in the groundwater in January 1997 was 2.9 mg/L. Groundwater monitoring results indicate that chromium concentrations have been reduced compared to initial levels, but not to levels below the treatment goal.
- Figure 2 illustrates the changes in average chromium concentrations in the groundwater from January 1992 to January 1997 [6]. Average chromium levels were reduced by 48% during that time, from 0.98 mg/L in March 1992 to 0.54 mg/L in January 1997.
- The individual wells provided wide variations in month to month chromium concentrations for the first two years. The variation became less pronounced in 1996 with a noticeable downward trend [9].
- Concentrations of chromium in the groundwater have fluctuated in different wells. Figure 3 illustrates that chromium levels in RW-1 and RW-5 increased from 1992 to 1995. Figure 4 illustrates well-specific chromium levels that decreased from 1991 to 1997, then fluctuated during 1994. Figure 5 illustrates well-specific chromium levels that decreased from 1986 until 1997 [4,6].
- The September 1994 sampling event revealed spikes in concentrations of chromium in many wells [7]. The site contact has indicated that while no QA/QC problems were identified, the validity of the September 1994 sampling event is questionable [6].
- Other spikes in concentrations of chromium may be a result of incomplete source removal. According to the site contact, source control measures were applied only to shallow soils. Because the ROD did not specify complete removal of soil contamination, additional soil removal was not performed.
- Figure 6 presents the removal of chromium through the treatment system from December 1993 to 1996 [1,5]. During this time, a total of 1,143 pounds of chromium were removed from the groundwater [1]. Chromium mass removal was determined based on the chromium concentrations in the sludge. Data on the amount of chromium removed by the treatment system during the 30-day period in 1992 were not available.
- Figure 6 illustrates that mass flux decreased after the first year of system operation, from 1.2 pounds per day to less than 0.8 pounds per day [1].

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

- Effluent chromium levels have met the required performance standard of 0.05 mg/L throughout treatment [6].

- Based on sampling events, plume containment has been achieved since 1995 [3,6]. The site operators determined there was a failure in plume containment during 1993 and 1995, based on a rise in chromium concentrations in some monitoring wells during this period [4]. Two monitoring wells within the area of concern were converted to recovery wells, and two recovery wells from a less contaminated area were taken off line.

Performance Data Completeness

- Data on mass flux and mass removed are reported on a monthly basis and are available for this site from the TNRCC. Annual data were used for the analyses in Figure 6.

- For the chromium concentration analyses in Figures 2 through 5, annual monitoring data were used for 1993 and 1995 through 1997. Quarterly data were used for 1994. These data were supplied in monthly reports and in the Project Status Draft Report prepared by ITC in 1995. Monitoring data are available on a quarterly basis for this site from the TNRCC.

- A geometric mean was used for average chromium concentrations detected in the groundwater, as presented in Figure 4, to represent the overall trend of chromium contamination in the groundwater at the site.

- When concentrations below detection limits were encountered, half of the detection limit was used for evaluation purposes.

Performance Data Quality

The QA/QC program used throughout the remedial action met EPA and TNRCC requirements. All monitoring was performed using EPA Method 218.1 and EPA-approved methods for pH, total suspended solids, and other water quality parameters. Except for the September 1994 data (discussed above) the vendor did not note any exceptions to the QA/QC protocols [6].

TREATMENT SYSTEM PERFORMANCE (CONT.)

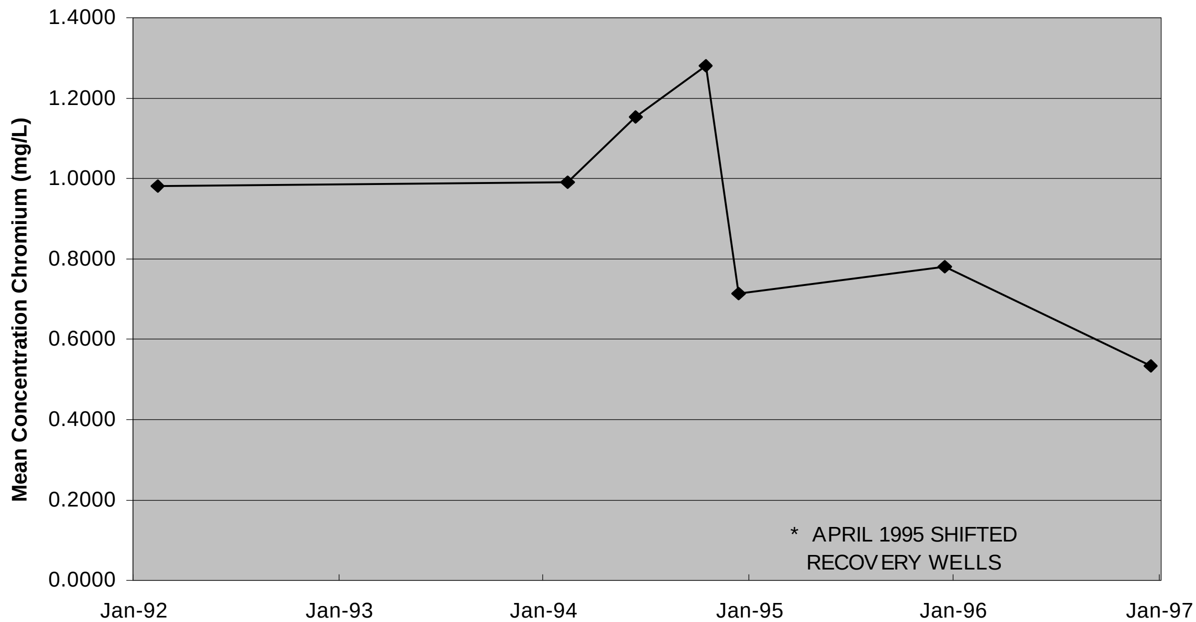


Figure 2. Average Chromium Concentrations in the Groundwater (1992 - January 1997) [4,6]

* Two monitoring wells converted to extraction wells; two other extraction wells shut down.

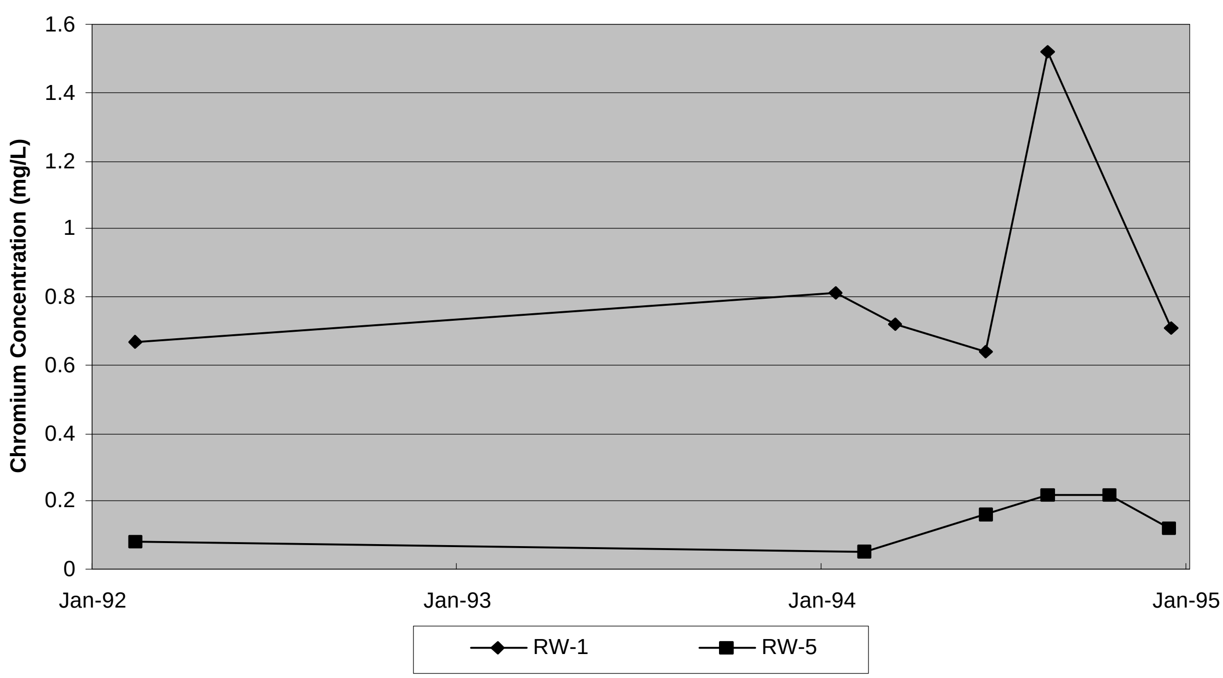
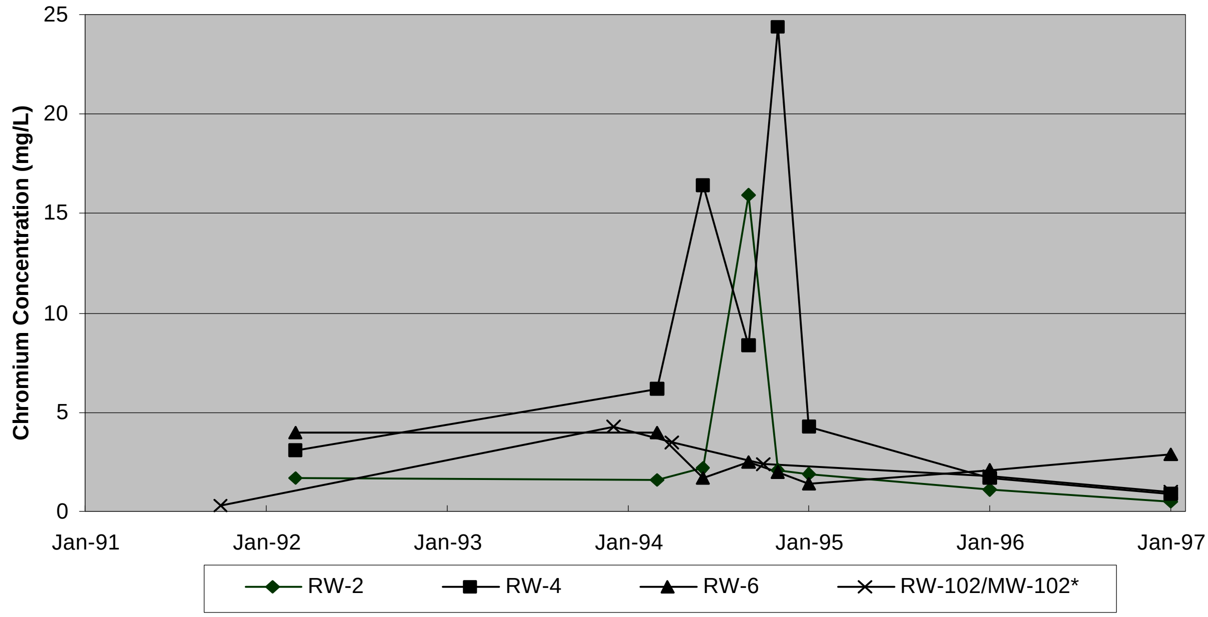


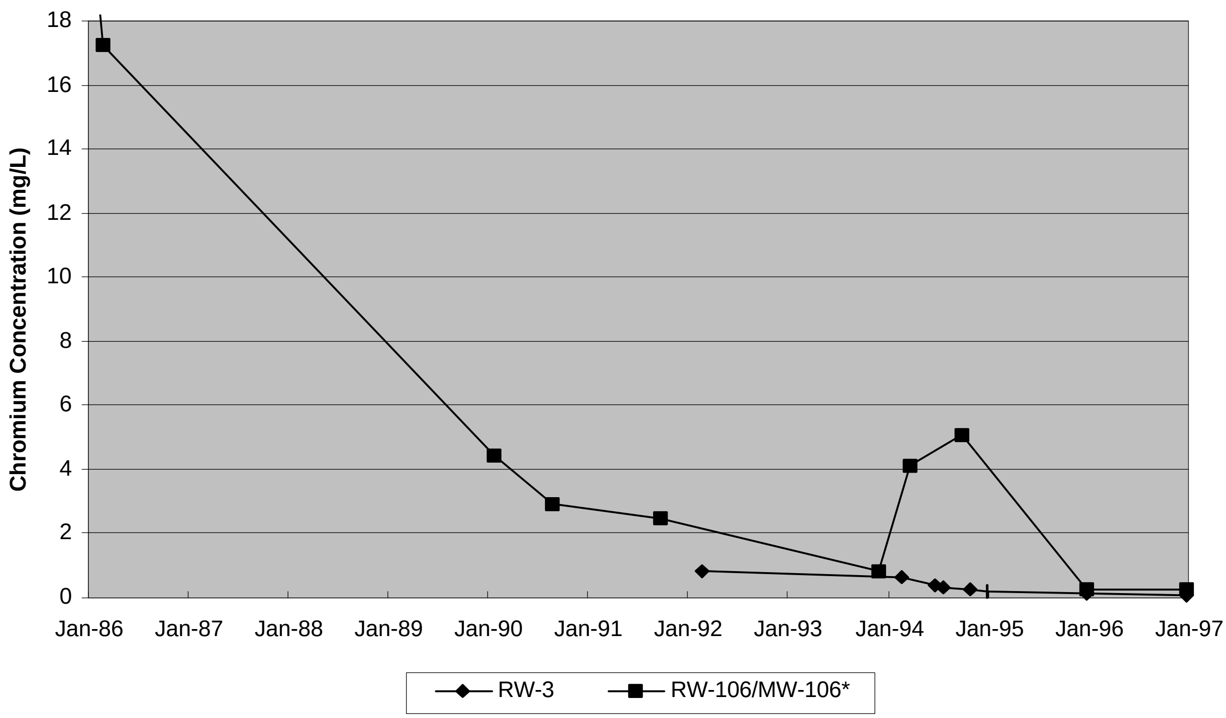
Figure 3. Chromium Concentrations in Wells RW-1 and RW-5 (1992 - 1997) [4,6]

TREATMENT SYSTEM PERFORMANCE (CONT.)



*RW-102 was MW-102 until 4/95

Figure 4. Chromium Concentrations in Wells RW-2, RW-4, RW-6, and RW-102 (1991 - 1997) [4,6]



*RW-106 was MW-106 until 4/95

Figure 5. Chromium Concentrations in Wells RW-3 and RW-106 (1986 - 1997) [4,6]

TREATMENT SYSTEM PERFORMANCE (CONT.)

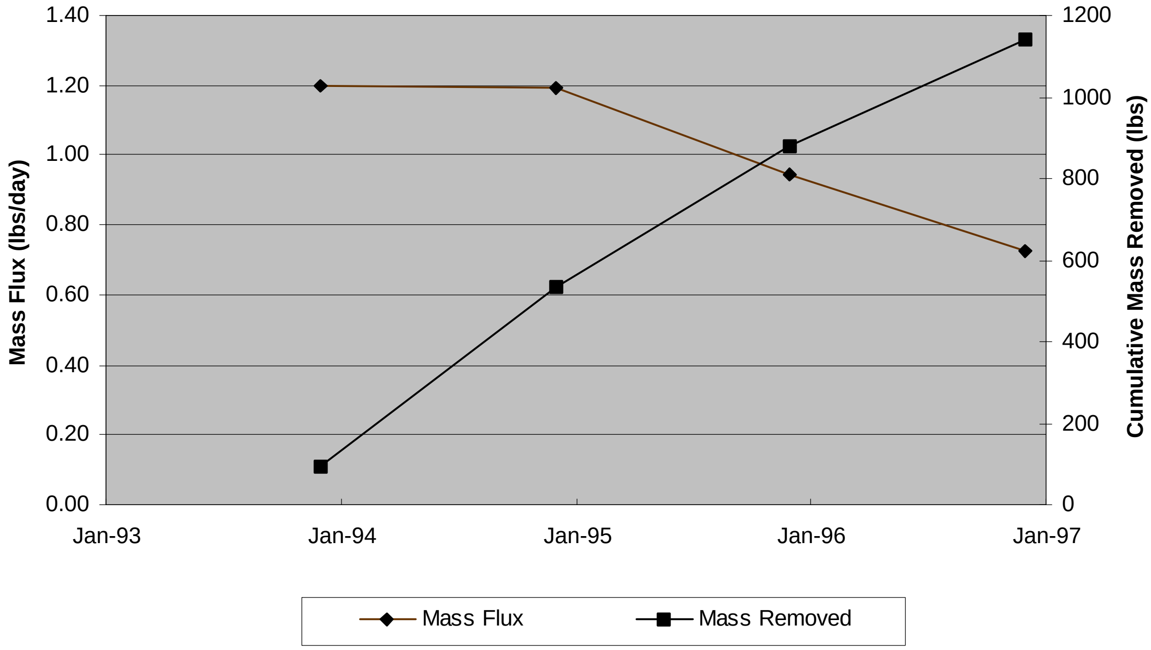


Figure 6. Mass Flux Rate and Cumulative Chromium Removal (1993 - 1996) [6]

TREATMENT SYSTEM COST

Procurement Process

TNRCC is the lead authority on this site. WATEC was awarded the construction and operations contract for the site. ITC was awarded the oversight contract for the site.

Cost Analysis

- The costs for design, construction, and operation of the P&T system at this site were split 90:10 by EPA and TNRCC, respectively.

TREATMENT SYSTEM COST (CONT.)

Capital Costs [6]

Remedial Construction	
Mobilization Work	$334,723
Monitoring Wells - Sampling/Testing Analysis	$52,761
Groundwater Collection & Control	$287,947
Installation of Treatment Plant	$944,800
Site Restoration	$13,542
Site Security	$3,298
Construction Management	$316,533
Total Remedial Construction	**$1,953,604**

Operating Costs [6]

Operation and Maintenance	$774,418
Monitoring Costs	$13,841
Total Cumulative Operating Expenses (1993-1996)	**$788,259**
1993 Operating Costs (11/93 - 12/93)	$25,772
1994 Operating Costs (1/94 - 12/94)	$202,817
1995 Operating Costs (1/95 - 12/95)	$228,705
1996 Operating Costs (1/96 - 12/96)	$330,965

Other Costs [6]

Remedial Design	
Original Bid Design	$132,180
Final Amount (redesign in 1993) (total for design)	$230,438

Cost Data Quality

Actual capital and operation and maintenance cost data are available from TNRCC for this application.

OBSERVATIONS AND LESSONS LEARNED

- Actual costs for the pump and treat application at Odessa I were approximately $2,742,000 ($1,954,000 in capital costs and $788,000 in operation and maintenance costs), which corresponds to $30 per 1,000 gallons of groundwater treated and $2,400 per pound of chromium removed. The $30 per 1,000 gallons is based on volume treated through December 1996, because cost data through 1998 were not available at the time of this report.

- The ROD specified that the ferrous ion used to reduce the chromium would be electrochemically produced, which limited the number of the on-site system vendors to two and potentially increased the cost of the treatment unit.

- The costs listed above include the system modifications performed in 1993 and in 1995. There have been no further changes to the cost for the remedial system at the site [3].

- Operating costs have increased from 1993 to 1996. The operations contract has a fixed annual cost for disposal of up to 500 lbs of chromium. Any amount of chromium beyond 500 lbs is paid on a cost plus fixed fee basis, resulting in additional annual disposal costs each year since 1993.

- While chromium levels have been reduced below the MCL in three wells, the groundwater cleanup goals have not been achieved as of December 1996. Extraction and treatment will continue until goals are achieved [3,4,6].

- Overall, average chromium concentrations decreased, but concentrations of chromium have fluctuated in some wells [4]. These variations in chromium levels are most likely a result of the increased groundwater level and further desorption of chromium from aquifer materials [3,7]. According to the site contact, because complete removal of all contaminated soils was not specified in the ROD, source control measures (i.e., soil removal) were applied to only shallow soils [4]. Deeper aquifer material may still contain high levels of chromium that can act as a source for continuing contamination [3,7]. The site contact also noted that complete source removal would have eliminated the source for a persistent plume [3].

OBSERVATIONS AND LESSONS LEARNED (CONT.)

- The plume has been contained since 1995, after containment failure from 1993 to 1995 [1]. The shift in groundwater flow observed in 1993 may have caused the containment failure [6]. By adjusting the extraction system, plume containment was achieved. This illustrates the importance of flexibility in system operation.

- There were several startup problems, including clogging of injection wells and filter by iron and calcium, that delayed full-scale operations [4]. These problems were solved through system modification, and no longer interfere with operations. The site contractor has suggested that one potential approach to identifying the problems earlier would be to increase the length of pilot operations. At this site, pilot operations were conducted in hourly increments, and the results were used to simulate full-cycle operations. Had the pilot operations been conducted for a full 24-hour cycle, it is likely that the iron and calcium fouling problems that led to clogging would have been identified [4].

- Full-scale operations were delayed by iron encrustation in the injection wells and in the filter. Setting effluent standards for iron in the future could prevent such delays.

- ITC also has concluded that the continuous chromium monitors on the influent were not useful because they could not detect chromium levels above 1.0 mg/L. They did not operate until wells were well on the way to being clean. Monthly tracking was found to be helpful for monitoring site cleanup, but continuous data were not useful [4].

- During system operation, system operators determined that backwash from the filter system should be equalized and added slowly to the influent tank to avoid large changes in the influent chemistry [4]. During early system operations, backwash water was introduced directly into the influent tank. The differences between the pH levels in the backwash and the influent reduced the effectiveness of the reaction tank. The backwash storage unit allows gradual addition of backwash to the influent. This has alleviated the earlier problems in the reaction tank [4].

REFERENCES

1. Record of Decision, USEPA, Odessa Chromium #1, OU2, March 18, 1988.
2. Record of Decision, USEPA, Odessa Chromium I, OU1, September 8, 1986.
3. Correspondence with Mr. Lel Medford, TNRCC.
4. Project Status Draft Report, ITC, January 1995.
5. Odessa Chromium I & IIS Superfund Sites Treatment System, WATEC. No date listed.
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7. Lessons Learned, ITC, January 1997.
8. Groundwater Regions of the United States. Heath, Ralph. U.S. Geological Survey Water Supply Paper 2242. 1984.
9. TNRCC comment on draft report, dated 3/11/98.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

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